Although sleep has not been studied in many wild birds, most species sleep for at least six to eight hours every day (see box on page 24). Migrating passerines, however, are unable to do so because they fly for much of the night and need to feed during the day. In 2004, a team of researchers led by Niels Rattenborg showed how captive White-crowned Sparrows sleep about two-thirds less during their period of migratory restlessness than at other times of the year (PLoS Biol. 7: 934). The migrating sparrows performed behavioural tasks with the same level of accuracy as birds outside the migration period that slept for about eight hours a day, suggesting that they suffered no ill effects from lack of sleep.

Remarkably, the same birds struggled to perform the tasks when they were restricted to three hours of sleep outside the migration period. However, we can’t exclude the possibility that the stress of experimentally preventing birds from sleeping may have contributed to their poor performance.

While on migration, the sparrows spent more time drowsing during the day, which may help to offset the lack of sleep at night. In 2006, Thomas Fuchs and colleagues observed how during the migration period, captive Swainson’s Thrushes undertook a series of ‘micronaps’ throughout the day (Annual Behaviour 72: 951–958). In 2009 they confirmed with an electroencephalogram (EEG) that the thrushes experienced short bouts of sleep lasting more than 30 seconds (Biolog Letters 5: 77–80). Migrating thrushes experienced short bouts of both USWS and BSWS during the day (averaging 11–13 seconds), but rapid eye-movement (REM) sleep only occurred at night and might not occur during migration.

While THE exact function of sleep remains elusive, virtually all animals with a nervous system experience periods of reduced activity and awareness. The fact that this occurs despite an increased risk of predation suggests that sleep plays an essential role in enabling the brain to function properly when animals are awake. Experiments confirm what we know from personal experience – sleep deprivation reduces the ability to concentrate, which has potentially lethal consequences for animals that need to remain alert for predators. Despite this, animals differ in both the amount and type of sleep they experience. Peter Ryan reports on recent studies that show that at least some birds have evolved mechanisms to manage with very little sleep for protracted periods.

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Birds such as this Red-necked Sturzfrau are most vulnerable to being killed by predators while asleep, so they have evolved numerous strategies to reduce this risk. These include roosting in groups and taking many short naps rather than undergoing a protracted period of deep sleep.
**HOW MUCH IS ENOUGH SLEEP?**

Sleep is a fundamental requirement: when an animal is sleep deprived, the need to sleep overrides the need to eat or the desire for sex. Reducing the amount of time rats sleep by 70 per cent or more results in their death within a few weeks. Yet surprisingly little is known about sleep duration in birds. A review by Roth et al. in 2006 (Journal of Sleep Research 15, 395–402) presented data for only 23 bird species, which sleep between six hours (Budgerigar) and 17 hours (Ring-necked Dove) a day.

Mammals are better studied and we know that the amount of time spent sleeping increases with body size, diet and risk of predation. Sleep duration typically decreases with age; babies sleep more than adults. Mammals with secure roost sites can afford to sleep for longer than those that are at risk of being eaten while sleeping. This was the only factor found to affect the duration of sleep among birds.

The frigatebirds’ extremely long, angled wings and large, deeply forked tails, coupled with a very light skeleton, confer the lowest wing loading of any bird species. This results in very efficient flight, frigatebirds soar effortlessly, routinely rising up to 600 metres above the sea using thermals or trade winds. From these lofty heights, they glide down when they spot a feeding opportunity. They rarely fed at night, when they typically remain 50 to 1500 metres above the sea. However, Weimerskirch’s team found that birds only show occasional, brief periods when their bodies are completely motionless, suggesting that they seldom sleep. Rattenborg and colleagues tested whether frigatebirds do actually sleep while gliding or soaring, but not while flapping. Sleeping occurred mainly when birds were climbing in elevation and were fairly high above the sea – conditions when there is little risk of a collision. As expected, they usually shut down one side of the brain at a time. While soaring, they usually kept the eye open on the side of the head towards which they were circling, to watch where they were going. However, this was not always the case; occasionally both sides of the brain went to sleep at once. More surprisingly, the birds also exhibited brief snatches of REM sleep.

Despite the ability to sleep on the wing, frigatebirds sleep less deeply and spend much less time asleep while flying (less than three per cent of the time) than when they are attending their nests (around 50 per cent of the time). Sleeping on the wing was more frequent at night (five per cent of the time) than during the day (0.4 per cent). Sleep bouts while flying averaged only 11 seconds, but the longest sleep bout was almost six minutes, so flying birds can occasionally take quite long naps.

There was some evidence that the frigatebirds acquired a sleep ‘debt’ during their foraging trips because of the reduced amount and quality of sleep in flight. On returning to their nests, the amount of time spent sleeping and the depth of that sleep decreased gradually during the first 10–15 hours ashore. Despite this, the average duration of sleep events was still only about one minute, suggesting that birds experience sleep quite differently from how humans do.

**Flying on autopilot**

**SHOREBIRDS SLEEP WHERE THEY CAN**

Shorebirds, along with other long-distance migrants, might also be able to get some sleep in flight. It has long been assumed that Common Swallows must sleep on the wing because they apparently remain aloft throughout their non-breeding period, which lasts about nine months. Radar observations confirm that non-breeding swallows climb to about 3000 metres above the ground at night, where they spend the hours of darkness cruising over their colonies. If sleep is indeed essential, they must sleep in flight. In 2006, Rattenborg predicted that birds should be able to sleep in flight, mainly using USWS but perhaps also brief periods of BSWS (Naturwissenschaften 93, 413–425). However, he thought that REM sleep was unlikely to occur in flight, as a result of the accompanying lack of muscle tone.

Testing these ideas required the development of an EEG small enough to be attached to a bird that remains aloft for days on end. Frigatebirds are the largest birds to do so and are renowned as seabirds that remain aloft for days on end. Fitting male sandpipers with EEGs revealed that the individuals that spent more time awake experienced deeper sleep during their short resting periods, but this doesn’t fully compensate for their limited sleep time. It is likely that they repay their sleep debt only if the females are no longer available for mating. Shorebirds probably also suffer sleep deprivation while on their long-distance migrations, which in extreme cases can result in birds flying non-stop for more than a week. Anecdotal evidence suggests that waders arriving in New Zealand after flying across the Pacific Ocean spend more time sleeping than feeding.

**A female Great Frigatebird equipped with a miniature EEG logger on its head and a back-mounted GPS logger soars over its breeding colony in the Galapagos Islands. Nick Rattenborg’s recent study of these birds was the first to confirm that birds can sleep in flight.**